AN INSTRUMENT FOR MEASURING FIRMNESS OF RED TART CHERRIES[1]

By R. E. PARKER, J. H. LEVIN[2], and R. T. WHITTENBERGER[3]

ABSTRACT

Of four instruments tested for their ability either to measure cherry firmness directly or to measure a closely related firmness parameter, only 1 was found acceptable. A modified commercial micrometer-dial gage successfully detected firmness variations by measuring the deflection of cherries subjected to a constant load applied over a constant area.

Such factors as cherry position, size, soluble solids content, and time allowed for the load to remain on the cherry were investigated for their effect on the instrument reading in standardizing a measuring technique. The sensitivity of the instrument to cherry firmness was evaluated by taking readings first on unbruised hand-picked fruit and again after application of known bruising treatments.

INTRODUCTION[4]

NEW AND IMPROVED TECHNIQUES of producing, harvesting, handling and processing red tart cherries are being developed each year. Mechanical shaking, hauling in water, electronic sorters, destemmers —all are relatively new to the cherry industry. In many instances, evaluation of a new technique on cherry quality has been based on its effect on cherry firmness.

---

[1] The work described was carried out jointly by Fruit and Vegetable Harvesting Investigations, Harvesting and Farm Processing Branch, Agricultural Engineering Research Division, and Eastern Utilization Research and Development Division, United States Department of Agriculture; and the Agricultural Engineering Department, Michigan State University, East Lansing.

[2] R. E. Parker and J. H. Levin are Agricultural Engineers, with the Agricultural Engineering Research Division, ARS, U.S.D.A.

[3] Research Biochemist, Eastern Utilization Research and Development Division, USDA, ARS, Philadelphia, Pennsylvania.

[4] Acknowledgements: The authors wish to express their appreciation to Richard Wolthuis and Leland Fitzpatrick, AERD, USDA for construction of most of the instruments described herein and for assistance in developing testing techniques and to Burnett Farms Packing Company, Keeler, Michigan for use of their facilities while conducting the investigations.

Reprinted from the QUARTERLY BULLETIN of the Michigan Agricultural Experiment Station, Michigan State University, East Lansing. Vol. 48, No. 3, pages 471 to 482, February 1966

Bedford[5] measured "firmness" with a tenderometer and reported the results in pounds per square inch. Whittenberger and Marshall[6] determined cherry firmness with a spring-loaded compression device. La Belle, et. al.[7] stated that the resistance of the cherry tissue to the shearing-crushing action of pitting is a more satisfactory guide to cherry firmness than the previously described techniques. A significant correlation between pitting force and juice loss during pitting was established.

In order to measure firmness in a manner approaching the human touch method, it would seem that a deflection measurement of a cherry subjected to a constant force over a fixed area should suffice. The result could be expressed as a fraction of an inch or as a percent of the original diameter. The latter criteria would apply if deflection is a function of the original cherry diameter. To be widely accepted, the instrument should (a) be simple to operate, (b) be inexpensive, and (c) consistently detect the effect of a small bruise on the cherry.

PRELIMINARY INVESTIGATIONS

Several attempts were made to measure cherry firmness directly or discover a parameter whose value was closely related to firmness. Most techniques are described briefly in this report to help prevent duplication of effort by other researchers. The apparatus shown in Fig. 1 was designed for measuring the time required for a cherry to roll a fixed distance down a given slope.

A correlation between time and cherry firmness was sought. However, it was insensitive to small differences between firmness of cherries and failed to yield satisfactory results in repeat tests. Cherries did not always roll down the board in a straight line. Excess cherry juice made the board surface sticky, which affected the coefficient of friction between the cherry and the board.

Cherries were dropped onto an inclined surface (Fig. 2). No relationship was apparent between length of bounce and cherry firmness. Various slopes, surface conditions and drop heights were tried without success.

Cherries stacked vertically and subjected to a specific force should compress a distance related to their firmness. Such an assumption was

---

[5] Proc. 92nd Annual Mich. St. Hort. Society Meeting (1962). Mechanical Harvesting of Cherries—A Panel Discussion.

[6] Whittenberger, R. T. and R. E. Marshall (1950). Measuring firmness of red tart cherries. Food Tech. 4 (7):311-312.

[7] La Belle, R. L., E. E. Woodams, and M. C. Bourne (1964). Recovery of Montmorency Cherries from repeated bruising. Proc. Amer. Soc. for Hort. Sci., Vol. 84.

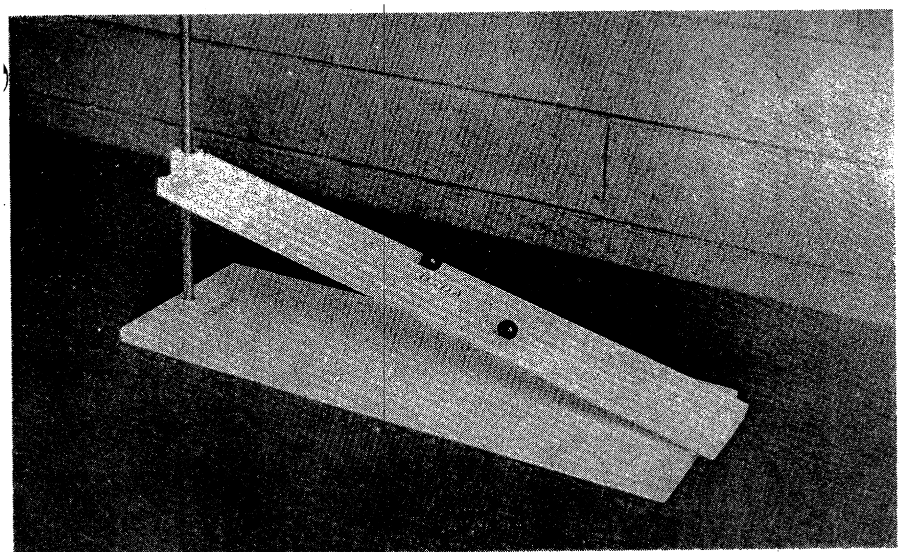

Fig. 1. Experimental apparatus used in an unsuccessful attempt to establish a relationship between cherry firmness and average velocity of cherries rolling down an angular plane.

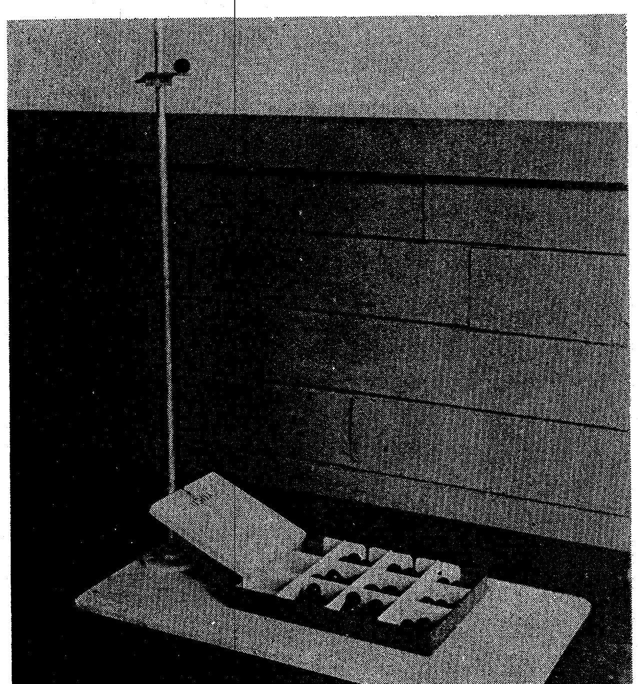

Fig. 2. The distance a cherry bounces from an inclined surface did not vary with the firmness of the cherry according to results obtained using the apparatus shown above.

checked with the instrument shown in Fig. 3. Ten cherries were held vertically in a tube and subjected to one-half pound or 1 pound loads. The distance the cherries settled under each load was measured for unbruised and deliberately bruised cherries. The instrument was successful in detecting the effect of a three-foot drop on the firmness of unbruised cherries, however, it failed to detect the effects from a second three-foot drop.

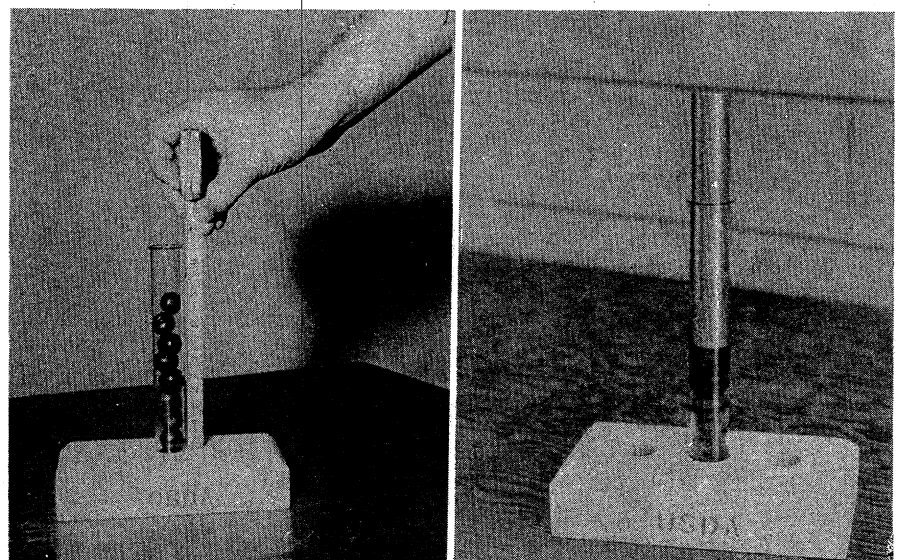

Fig. 3. Measuring cherry firmness by compaction. Small cherries did not stack vertically (left) and softer cherries trapped air in the tube (right). Both faults had a pronounced effect on results.

This failure was due primarily to the fact that the softer cherries expanded more in their horizontal diameter and consequently trapped air between them. The trapped air prevented the cherries from settling under the weights as much as they should have.

To overcome the trapped air problem, a larger tube could have been used. However, cherries would no longer be stacked in a vertical line if the diameter of the tube were sufficiently larger than the diameter of the largest cherry. Other problems encountered with this system were (A) friction between the cherries and tube wall supported some of the load, (B) uncontrolled position of the cherries as they are being stacked, (C) tube size must be selected according to cherry size to maintain a vertical stack, (D) bottom cherries must support weight of cherries above them in addition to the plunger weight, and (E) cherries were damaged to such an extent as to make it impractical to run a duplicate test on the same cherries.

INSTRUMENT DESCRIPTION AND TECHNIQUE

The most satisfactory firmness-measuring instrument was developed to measure cherry diameter rapidly. It was later discovered that the cherry settled slightly due to the small force applied by the instrument. Since the instrument satisfied the first two conditions for acceptance as a firmness measuring device, it was tested for sensitivity to cherry firmness.

The cherry firmness measuring instrument (hereafter referred to as the PL meter) consisted of a rigidly mounted micrometer dial with its rod vertical. The dial was graduated in .001 inch and the spring which is normally attached to the dial rod was removed in order to maintain a constant force on the cherry. The weight of the rod, and consequently the force applied to the cherry, was 16 grams and the diameter of the rod tip was .203 inch. Consequently, the cherry area over which the 16 grams was applied was .0324 square inches.

Individual cherries were placed under the PL meter with their stem axis vertical and stem end down as shown in Fig. 4. The PL meter reading at the point of contact between its rod and the cherry was recorded as the initial cherry "stem diameter."

The instrument rod was released and allowed to settle for two minutes. Usually the descent of the rod ceased after one minute on unbruised cherries. It required between one and two minutes for rod descent to cease on severely bruised cherries. A final reading was made at the end of the two minute period. The difference between initial and final readings was recorded as inches of deflection. Percent deflection was calculated by dividing the deflection by the initial cherry diameter times 100.

The cherries were placed under the PL meter in the same position, namely, stem axis vertical with stem end down. The importance of cherry position is evident by the results given in Table 1. Deflections were measured on five cherries, each lying in three different positions. The deflection, as well as percent deflection, depends upon the cherry position. The stem-end-down position was selected as the standard because of the simplicity of placing the cherry consistently in the same position.

Preliminary investigations revealed that the temperature variations between 40° and 80° F. had no affect on the PL meter reading. Therefore, temperature need not be considered when measuring firmness.

METHOD OF EVALUATING PL METER PERFORMANCE

This experiment was designed to correlate PL meter readings with cherry firmness. Cherry firmness was altered by dropping the cherries a distance of 3 feet a specific number of times. PL meter readings were taken on each cherry before and after each drop to determine the effect of the bruising treatment on cherry firmness. The results are not intended for use as a basis for making conclusions about the behavior of cherry firmness itself. They are intended merely to indicate the sensitivity of the instrument to firmness and to establish a range of meter readings for cherries subjected to known treatments.

First of all, PL meter readings were taken on unbruised, handpicked cherries to establish the range of values which represent cher-

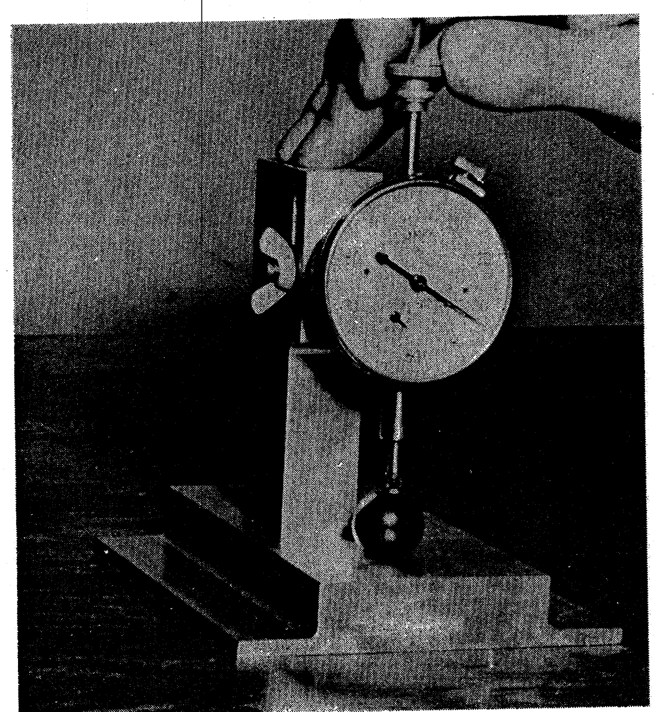

Fig. 4. PL meter developed for measuring cherry firmness July, 1965. Cherries were placed under the meter with their stem axis vertical and stem end down.

TABLE 1—Effect of cherry position on PL meter readings

Cherry position	Cherry identification	Initial diameter, inches	Deflection	
			Inches	Percent
Stem End Down-Stem Diameter Vertical	a	.689	.043	6.24
	b	.677	.042	6.20
	c	.705	.061	8.65
	d	.692	.039	5.64
	e	.663	.040	6.04
	Average	.685	.045	6.55
Suture Side Down-Suture Diameter Vertical	a	.717	.045	6.28
	b	.698	.049	7.02
	c	.714	.067	9.39
	d	.710	.042	5.92
	e	.679	.054	7.96
	Average	.703	.051	7.31
Cheek Diameter	a	.758	.049	6.47
	b	.755	.062	8.22
	c	.781	.085	10.88
	d	.763	.046	6.03
	e	.730	.056	7.67
	Average	.757	.060	7.85

ries in their unaltered condition. Nine hand-picked cherries of approximately equal color were divided into three equal groups according to size—small, medium and large. Softness of each cherry was measured by the PL meter at 2, 5, 8, 11, 23 and 30 hours after harvest. During this interval, the cherries were kept in atmospheric air. Air temperature varied from about 60° to 80° F. This condition would be similar to that achieved by a grower carefully hand-picking cherries and holding them overnight in air before delivering them to the processor.

A second test consisted of hand harvesting 45 cherries at random and measuring the firmness of nine unbruised cherries two hours after harvest then dropping them a distance of three feet twice. Firmness was measured after each drop. Soluble solids were measured by a hand refractometer after the final firmness readings. The procedure was repeated on nine more cherries of the original 45, five hours after harvest and again 8, 11 and 24 hours after harvest. This test was designed to determine the ability of the PL meter to detect bruising of the cherry any time after harvest. Soluble solids were checked to determine the effect of this characteristic on the instrument sensitivity and firmness of bruised and unbruised cherries.

A third test included checking the firmness of 10 cherries as they were received in water at the Burnett Farms Packing Company, Keeler, Michigan and comparing their firmness with that of 10 apparently good cherries extracted from the sorting table just prior to the pitting operation. These firmness values were also compared with firmness values of the hand-picked unbruised and bruised cherries determined by test number two.

RESULTS

The firmness of unbruised hand-picked cherries as measured by the PL meter is reported in inches of deflection in Fig. 5. Note the

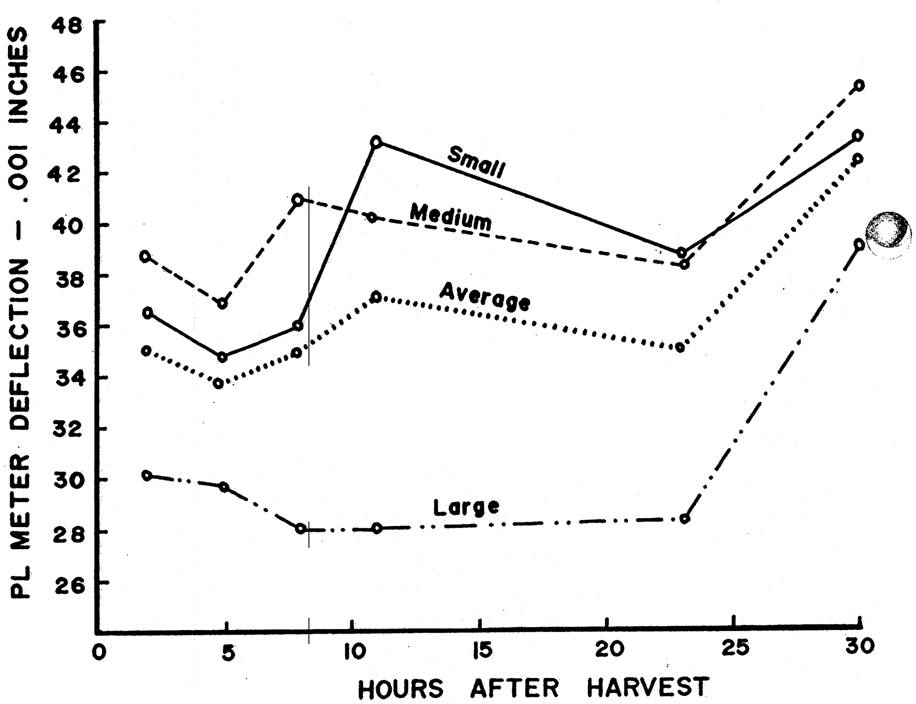

Fig. 5. Firmness of hand picked, unbruised cherries as measured with PL meter at specified intervals up to 30 hours after harvest. Each point represents the average deflection for three cherries in each size group. Cherries were harvested at Keeler, Michigan on July 15, 1965.

higher the deflection, the softer the cherry. Initial deflection measurements made two hours after harvesting indicated that deflections were independent of cherry size.

Although the average deflection of the three large cherries was considerably below that of the three medium and small cherries, the difference was probably due to the fact that one of the three large cherries was unusually low in soluble solids (13.2 percent as compared to 14.4 - 21.2 percent for all others). The average weights of the small, medium and large cherries represented in Fig. 5 were 3.09, 3.79 and 4.60 grams per cherry, respectively.

To illustrate the effect of soluble solids on cherry firmness, the nine cherries tested in each of the two and five hours-after-harvest intervals were grouped according to soluble solids levels and their averages were plotted versus deflection readings (Fig. 6). There was no apparent relationship between soluble solids and deflection readings provided soluble solids were greater than 14 percent.

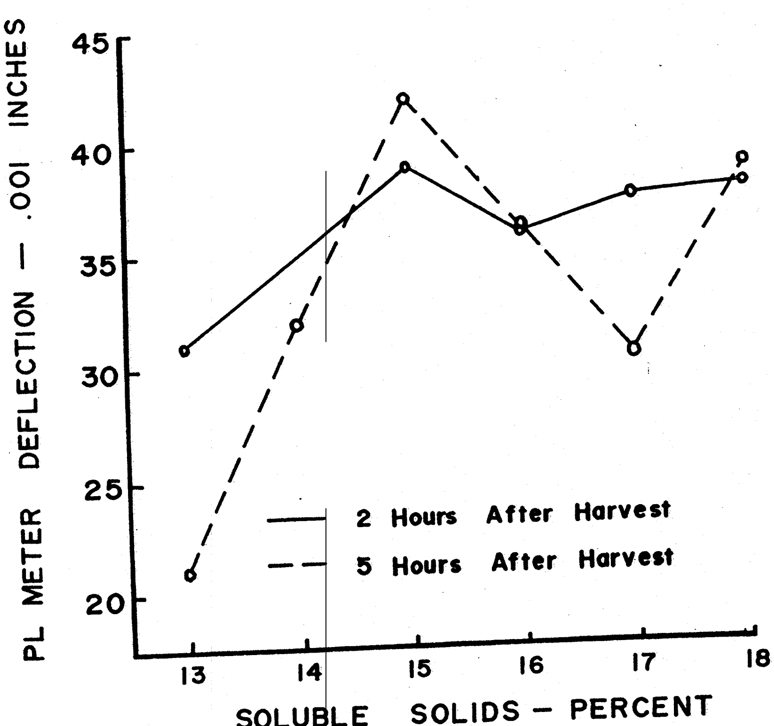

Fig. 6. Firmness measurements on unbruised cherries grouped according to soluble solids content two and five hours after harvesting by hand at Keeler, Michigan July 15, 1965.

Cherries containing less than 14 percent soluble solids had the lowest deflection for both time-interval categories. Soluble solids should be considered when measuring cherry firmness with the PL meter if the cherries have less than 14 percent soluble solids. Mature cherries are much softer than immature cherries, and much higher in soluble solids.

A second experiment was designed to test the ability of the PL meter to detect after-harvest bruising. Deflection readings were taken on nine unbruised cherries for each time interval of 2, 5, 8, 11 and 24 hours after harvest. The nine cherries were then dropped three feet twice. Deflections were measured again immediately after each drop. Average deflections are shown in Fig. 7. The PL meter consistently

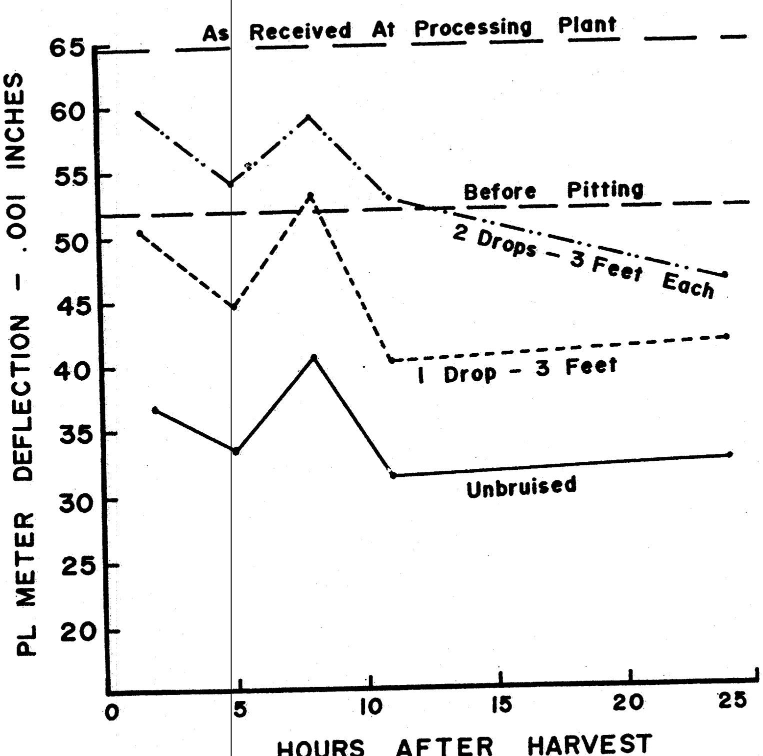

Fig. 7. Sensitivity of the PL meter to effects on cherry firmness of one and two drops of three feet each. Each point represents the average reading on nine cherries. Straight lines representing cherries as received at the plant and immediately prior to pitting represent average readings on ten cherries each and are intended for comparison with known bruising treatments only.

detected the effect of each drop on the firmness of the cherry. Visually, all cherries remained in an acceptable processing condition after bruising.

The average firmness of 10 mechanically harvested and apparently excellent cherries, as received at Burnett Farms Packing Plant, Keeler, Michigan, was plotted as a straight line in Fig. 7 to serve as a basis for comparing the severity of the controlled bruising treatments on unbruised, hand harvested cherries. The average firmness of 10 other acceptable cherries taken from the plant's sorting table (the soak time and harvesting method were unknown in this case) was also drawn as a straight line in Fig. 7.

Although no conclusions may be made from this data regarding the firmness of cherries as they are received and after soaking at the processing plant, it can be concluded that the PL meter was consistent in detecting the effect of only one three-foot drop on cherry firmness and that such a degree of bruising was far less than commercially-run cherries received during the harvest and handling operations prior to pitting at this particular plant.

SUMMARY

A modified commercial micrometer-dial gage was mounted rigidly on a stand and used to measure cherry diameter and deflection under a known load distributed over a known area. Such factors as cherry position, size, soluble solids content, and the time the load remains on the cherry were investigated in an attempt to standardize the measuring technique. Upon establishment of a standard technique, the sensitivity of the instrument to cherry firmness was evaluated by taking readings first on unbruised hand-picked cherries and again after the same cherries had been subjected to known bruising treatments.

The following measuring technique was adopted:

1. Place the cherry under the PL meter with stem axis vertical and stem end down since cherry position affected the instrument reading.
2. Read PL meter at point of initial contact between the instrument rod and the cherry.
3. Release instrument rod and take final reading two minutes later. Two minutes was always sufficient time for the rod descent to cease.

Express cherry firmness as thousandths of an inch deflection by subtracting final instrument reading from initial reading. Since cherry size did not affect deflection, this factor need not be considered when comparing firmness values.

The ability of the PL meter to detect slight bruising effects on cherry firmness was evaluated by subjecting unbruised cherries to known bruising treatments. The meter consistently detected the effect of a three foot drop on cherries. This bruising treatment had less effect on cherry firmness than normal harvesting and handling operations prior to pitting.

CONCLUSIONS

1. The PL meter described in this report was found to be simple to operate, inexpensive and very sensitive to cherry firmness when used according to the procedure outlined.
2. The instrument test did not affect the firmness of the cherries. Therefore, it is possible to take measurements again on the same cherries after soaking, handling or other treatments.
3. The instrument gave consistent readings on the same cherry provided the readings were taken within a short period of time.
4. The principle disadvantage in using the PL meter was its relatively low capacity (only 24 cherries per hour).